Neural Communication

Membrane transport

Permeable = if a substance *can* cross the membrane

Impermeable = if a substance *cannot* pass

Selectively Permeable = permits some particles to pass through while excluding others

Two properties of particles that influence whether they can pass membrane without assitance:

1. the relative solubility of the particle in lipid
    a. uncharged or nonpolar molecules can pass
        i. O2, CO2, and fatty acids
    b. charged particles and polar molecules have low solubility
        i. Na+ and K+, glucose and proteins
2. the size of the particle

Two general types of forces involved in transport across the membrane:

1. Passive Forces = forces that do not require the cell to expend energy to produce movement
2. Active Forces = forces requiring cell energy (ATP) expenditure to transport a substance across the membrane
    a. Need ATP
    b. Low to higher
    c. Against concentration gradient

Diffusion = uniform spreading out of molecules due to their random intermingling

Concentration Gradient = a difference in concentration between two adjacent areas

Net Diffusion = difference between two opposing movements

Steady State = movements of molecules from two different areas will be exactly matched going both ways.

Fick's Law of Diffusion:

Used in steady state (no change) and in non-steady state (diffusion volume changes with respect to time

1. ***high concentration gradient of substance (ΔC***), effect on rate of net diffusion goes ***up***
2. ***high permeability of membrane to substance (P)***, effect on rate of net diffusion goes ***up***
3. ***high surface area of membrane (A*)*,*** effect on rate of net diffusion goes ***up***
4. ***high molecular weight of substance (MW)***, effect on rate of net diffusion goes ***down***
5. ***high distance (thickness) (ΔX),*** effect on rate of net diffusion goes ***down***

Electrical Gradient = difference in charge between two adjacent areas that promotes the movement of ions toward the area of opposite charge.

Electrochemical Gradient = the net effect of simultaneous electrical and concentration gradients on this ion.

Carrier-mediated Transport

Carrier – Mediated Transport = carrier proteins span the thickness of the plasma membrane and can reverse shape so that specific binding sites can alternately be exposed at either side of the membrane.

- carrier "filp-flops" so that binding sited located in the interior of the carrier are alternately exposed to the ECF and ICF.
- Carrier –mediated transport systems desplay three important characteristics that determine the kind and amount of material that can be transferred across the membrane: *specificity, saturation, and competition*.
    - **Specificity.** Each carrier protein is specialized to transport a specific substance, or at most a few closely related chemical compounds.
    - **Saturation.** A limited number of carrier binding sites are available within a particular plasma membrane for a specific substance. This limit is known as the *transport maximum* ™.
    - **Competition.** Several closely related compounds may compete for a ride across the membrane.
        - Slows down transport.
- all membranes have electrical properties because of unequal distribution of charges.
- Membranes are polarized (seperation of charges)
    - Takes work to separate opposite charges
    - Potential to do work if brought together
    - Membrane potential refers to separation of charges if equal both sides – no potential to do work

1. Facilitated Diffusion = uses a carrier to facilitate (assist) the transfer fo a particular substance across the membrane "downhill" from high to low concentration. (No energy required)
2. Active Transport = requires the carrier to expend energy to transfer its passanger "uphill" against a concentration gradient, from an area of lower concentration to and area of higher concentration.
    a. Require energy
    b. Chemical energy transferred directly from ATP to carrier
    c. Carrier acts as enzyme to catalyst their own phosphorylation
    d. When the carries phosphorylated the greater affinity between it and its passanger molecules.
    e. When the passanger molecule binds the carrier it produces a conformation change in the carrier.
        i. Passenger molecules are exposed to outside.

3. Na+ - K+ PUMP = carrier transports Na+ out of the cell, concentrating it in the ECF, and picks up K+ from the outside concentrating it in the ICF.
    a. It establishes Na+ and K+ concentration gradients across the plasma membrane of all cells.
    b. It helps to regulate cell volume by controlling the concentrations of solutes inside the cell and thus mimimizing osmotic effects tha twoudl induce swelling or shrinking of the cell.

Factors Contributing to Unequal distribution:

1. non-diffusible anions inside
2. actions of Na+ - K+ pump
3. permeability properties of membrane are at rest
    a. membrane is more permeable to K+ at rest than Na+

True or False: It takes energy to get K+ in but it doesn't take energy to get it out?

True

Excitable Tissues = the ability to produce rapid, transisent changes in their membrane potential when excited

- nerve cells and muscle cells

Resting Membrane Potential = the constant membrane potential present in the cells of a nonexcitable tissues and those of excitable tissues when they are at rest – not producing electrical signals.

Polarization = charges are separated across the plasma membrane, so that the membrane has potential.

- any time value of membrane potential is other than 0 mV (+ or -), the membrane is in a state of polarization

Depolarization = a change in potential that makes the membrane less polarized (less negative) than at resting potential.

- decreases membrane potential by moving it closer to 0 mV.

Repolarization = the membrane returns to resting potential after having depolarized.

Hyperpolarization = a change in potential that makes the membrane more polarized (more negative) than at resting potential.

- moves farther from 0 mV

Voltage Gated Channels = channels that open or close depending on voltage present. Response to changes in membrane potential.

Chemically Gated Channels = change conformtion in response to the binding of a specific chemical messenger with a membrane receptor in close association with the channel.

Mechanically Gated Channels = respond to stretching or other mechanical deformation.

Thermally Gated Channels = respond to local changes in temperature (heat or cold).

Graded Potentials:

- short distance signals (direct within minutes)
- strength **IS** proportional to the triggering event.
    - Naptor potential
    - Postsynaptic potentials
    - Receptor potentials
    - End-plate potentials
    - Pacemaker potentials
    - Slow-wave potentials

Action Potentials:

- long distance signal
- not decimental
- strength is **NOT** proportional to the stimulus
- conducted (propagated) throughout the entire membrane in *nondecremental* fashion.
- Are all-or- none events
- One way of conduction of an electrical impulse is because of the refractory period

- Refractory period = new action potentials cannot be initated by normal events in a region that has just undergone action potential

A. Threshold potential = the critical potential that must be reached before an action potential is initiated in an excitable cell.
    a. Between -50 and -55mV
B. All-or-none Law = an excitable membrane either responds to a triggering event with a maximal action potential that spreads nondecrementally throughout the membrane, or it does not respond with an action potential at all.

Neuron

A single nerve cell (neuron) typically consisits of three basic parts: the cell body, the dendrites, and the axon

A. Cell Body = the nucleus and organelles are housed
B. Dendrites = numerous extensions to increase the surface area available for receiving signals from other nerve cells.
    a. Carry signals *toward* cell body.
C. Axon = a single, elongated, tubular extension that conducts action potentials *away from* the cell body and eventually terminates at other cells.
    a. Axon Hillock = the first portion of the axon plus the region of the cell body from which the axon leaves.
        i. The trigger zone, because it is the site where action potentials are triggered (initiated) by the graded potential if it is of sufficient magnitude.

Afferent = bring electrical impulse from periphere to CNS
- all have recptors
- EX: light stimulates receptor – brings into CNS

Efferent = EXIT
- inter neurons – lie entirely within the CNS
- brings message away

Myelinated Fibers

- Myelination increases the speed of conduction of action potentials

Myelinated Fibers are covered with myelin at regular intervals along the length of the axon.

Myelin = an insulative lipid covering that surrounds myelinated nerve fibers at regular intervals along the axon's length; each patch of myelin is formed by a separate myelin forming cell that wraps itself jelly-roll fashion around the neural axon.

- Oligodendrocytes = myelin-forming cells in the CNS (brain and spinal cord)
- Schwann Cells = myelin-forming cells in the PNS (the nerves running between the central nervous system and the various regions of the body)
- Nodes of Ranvier = the axonal membrane is bare and exposed to the ECF.
    - Saltatory Conduction = impulse "jumps" from node to node
    - Multiple Sclerosis (MS) = nerve cells become demyelinated
        - Is autoimmune, therefore, body's defense system attacks the myelin sheath surrounding myelinated nerve fibers

Innervate = a neuron terminates on a muscle or gland.

Synapse = junction between two neurons.

A. Presynaptic Neuron = conducts action potential toward the synapse
    a. Synaptic Knob = slight swelling at end of presynaptic neuron
        i. Synaptic vesicles = store a specific chemical messenger
            1. Neurotransmitter
B. Postsynaptic Neuron = the neuron whose action potentials are propagated away from the synapse.
    a. Synaptic Cleft = space between the presynaptic and postsynaptic neurons.
C. Action of a Synapse
    a. An action potential is propagated to the terminal of a presynaptic neuron.
    b. Ca^2+ (calcium) enters the synaptic knob (presynaptic terminal).
    c. Neurotransmitter is released by exocytosis into the synaptic cleft.
    d. Neurotransmitter binds to receptor sites on the postsynaptic neuron.
    e. Specific ion channels open in the subsynaptic membrane.
D. Inhibits of the Postsynaptic Neuron:
    a. Excitatory Postsynaptic Potential (EPSP)
        i. Negative, increase permeability of Na+
        ii. Na+ diffusion in
        iii. Depolarizing of membrane and comes closer to threshold.
    b. Inhibitory Postsynaptic Potential (IPSP)
        i. Increase the permeability of K+
        ii. K+ diffuses out
        iii. Hyperpolarization of membrane, because less positive inside
        iv. Further from the threshold
    c. IPSP – Graded Potentials
        i. Increase in permeablilty in Cl-
        ii. Chloride diffusion in
        iii. Hpyerpolarize because negative inside
        iv. Membrane further from threshold
    d. Grand Postsynaptic Potential (GPSP)

i. Sum of all EPSP and IPSP that are occurring at the same time on the postsynaptic neuron.

E. Temporal Summation = the summing of several EPSPs occurring very close together in time because of successive firing of a single presynaptic neuron.
F. Spatial Summation = the summation of EPSPs originating simultaneously from several different persynaptic inputs. (points have space)
G. EPSP and IPSP Cancellation = excitatory and inhibitory input are simultaneously activated, canceling each other out.
H. Convergence = many presynaptic imputs converging on postsynaptic
I. Divergence = branching of presynatic imputs on postsynaptic

Central Nervous System

- no nerves in CNS
- nerves = bundle of neural axon traveling together in same direction to PNS
- gray matter = do not have myelin
- white matter = does have myelin

A. Glial Cells
    a. 95% of cells
    b. support neurons both physically and metabolically
    c. types:
        i. Astrocytes:
            1. Main glue of CNS
            2. Help establish the Blood-brain Barrier
            3. Will take excess potassium
        ii. Oligodendrocytes:
            1. Form myelin sheets on axons of the CNS
        iii. microglia
            1. at rest these cells release a low level of neuron growth factor
            2. immune defense cells of CNS
            3. highly mobile
            4. can divide
        vi. ependymal cells:
            1. help form cerebral spinal fluid
            2. provide protective padding

- Nerve tissue cannot repoduce
- Needs protection:
    - Skull

    - Vertebrae
    - Meningies – found between bone and nervous tissue
    - Cerebral spinal fluid
    - Blood-brain Barrier

- cerebrovascular accidents (strokes)
- glutamate = binds to nearby cells – over excitement leads to chemical reaction damage
- Endothelial Cells
    - Tight junctions
    - O2 and CO2 can pass through (alcohol, steroid hormones)
- most synapse at the brain stem
- Vagas Nerve = wondering nerve

Parts of the Central Nervous System:

A. The Brain Stem
    a. Consists of the: midbrain, pons, and medulla
    b. Life-sustaining processes
    c. Posture and balance
    d. Arousal
    e. Reticular Formation
        i. Higher brain waves, nerves

B. cerebellum
    a. conatains:
        i. outer gray matter
        ii. inner white matter
    b. receives input from propioceptors
        i. afferent information = towards the CNS
    c. coordination of movement
        i. controls posture and balance
    d. ataxia
        i. damage to cerebellum
        ii. disfunction in speed, coordination, and strength

C. Forebrain:
    a. Cerebrum
        i. Cerebral cortex
            1. Thin layer of gray matter
            2. Separated into left and right hemisphere
            3. Heavily folded to keep weight down
                a. Gyri
                b. Sulci
            4. thought, voluntary movement, speech, and intellect

5. hemispheres connected by axons:
    a. corpus callosum
    b. left – right : right – left

ii. Basal Nuclei

b. Diencephalon: central core of brain
    i. Thalamus
    ii. Hypthalmus
    iii. Most complex: brings together afferent info. Images and motor activites.

D. Lobes Of Brain:
    a. Occipital Lobe = vision (posterior)
    b. Temporal Lobe = auditory
    c. Parietal Lobe =
        i. Separated by central sulcus
        ii. Sensory, body surface = somesthetic
        iii. Position of body = propioception
        iv. Somatosensory cortex = each region receives info from different body part.
    d. Frontal Lobe:
        i. Voluntary motor acivity
        ii. Speech and thought
        iii. Primary motor cortex

- Language = left hemisphere
    - Broca's Area: left frontal
        - Speaking ability
    - Wevnick's Area:
        - Comprehension of speech (spoken and written)

E. Subportical Structures
    a. Basal Nuclei:
        i. Inhibit muscle tone
        ii. Selectively maintain useful motor activity while inhibiting useless motor activity
    b. Thalamus:
        i. Major synaptic relay station
        ii. Go there to synapse then sent else where
        iii. Direct attention to important stimuli
        iv. Crude awareness of objects
        v. All sensory sent there
            1. Except olfactory (scent)

    c. Hypothalamus:
        i. Blood sampler
        ii. Critical in homeostatic regulation
            1. Body temp., thirst, appetiate, sex, water, balance, emotions

iii. indicates shivering
iv. causes blood vessels to constrict

d. Limbic System:
i. Forebrain structures
ii. Emotions
iii. Survial behavior
iv. Sex
v. Motivation / emotions
vi. Learning

Peripheral Nervous System (PNS)

Consists of everything for nervous system except for brain and spinal column

Afferent Division

- bring information to CNS
- Sensory Stimuli
- Visceral Stimuli
- Adequate Stimuli: type of energy that activates particular receptor
- Law of Specific Nerve Energy:
    - Activated other than adequate stimuli
    - Any given stimuli, receptor 1 type of reaction

A. Types of Receptors:
    a. Thermo Receptors = temperature
    b. Photo Receptors = image / color
    c. Chemo Receptors = chemical
    d. Baro Receptors =
    e. Osmo Receptors =
    f. Nocio Receptors =
    g. Mechano receptors = physical deformation

- some adapt and some do not
- Phasic =
    - Burst of firing stimulation
    - Quickly decreases
    - Off response
- Tonic =
    - Constant rate of firing as long as stimulus maintained

B. Pain Receptors
    a. Do not adapt

b. 3 categories
    i. mechano = cutting, crushing, pinching
    ii. thermo = temperature change
    iii. polymetal = all types including chemicals released from damaged cells.
c. 2 types of Fibers
    i. Adelta Fibers:
        1. Large myelinated fibers
        2. Fast pathway
        3. Mechano and thermal involved
    ii. C Fibers
        1. Slow unmyelinated
        2. Polymotal

- Antogensics Center:
    - Endogenous opiates
        - Endorphins

Efferent Division

- Somatic Nervous System
    - Motor neuron
    - Skeletal
- Autonomic Nervous System
    - Sympathetic
    - Parasympathetic
        - Smooth

- Autonomic Nervous System
    - Involuntary
    - Opposing effects
    - Tonic activity
        - Any given time both dual innervation
        - Fight or flight: sympathetic dominants
        - Feed and Bread: Parasympathetic (rest)
- exceptions to dual innervation:
    - blood vessels
    - sweat glands (sympathetic)
    - adrenal glands (sympathetic)
    - salivary (sympathetic and parasympathetic)

- Parasympathic:
    - Brain and terminal
    - Terminal ganglion
    - Pre and post ganglionic fiber
    - 1^{st} = long
    - 2^{nd} = short

- sympathetic:
    - thoracic or lumbar of CNS
    - close
    - 1st = short
    - 2nd = long

- Neurotransmitters:
    - Acetylcholine – pre
    - Epinephrine
    - Norepinephrine – post

- Acetylcholine:
    - Cholinergic receptors
        - Nicotinic = receptor for ACH on post
        - Muscarinic = receptors of ACH that are on organs
- Epinephrine:
    - Adreniergic receptors
        - Alpha 1:
            - Binds with NE –> activation of Ca++ 2nd messenger system
        - Alpha 2:
            - Blocks cyclic amp production – inhibitory response
        - Beta 1:
            - Activation of cyclic amp 2nd messenger system – excitatory response = increased heart rate and response.
        - Beta 2:
            - Activation of cyclic amp 2nd messenger system – inhibitory response
                - Smooth muscle relaxation in the respiratory airways – dilation

- Cell bodies of motor neurons can be destroyed by polio virus = paralyze
- Motor end Plate = binds
- Action potential goes both ways on muscle fibers = smooth muscle
- To relax muscle:
    - Acetylcholinesterase = stops action potential to relax contraction
- Organophosphates:
    - Inhibit ACH = prolonged contraction

-Myasthemia Gravis = autoimmune disease – destroys

Skeletal Muscles

- voluntary
- multinucleated
- muscle to bone
- bundle of muscle fibers – cell – muscle
- 1 muscle bundle fiber = muscle myofibril
- myofibril = repeating units of sacromere

Sacromere:

- thick filaments = myosin
- protrusions = cross bridges
    - cross bridges
        - ATP to bind
        - Actin
- thin filaments = actin
    - Actin in helix, two components:
        - Tropomyosin
            - Covering all binding sites of actin when not contracting
        - Troponin
            - Stabilizes tropomyosin to binding sites.
- Power Stroke = bending in of thin filaments of sacromere

What triggers contraction?

Calcium

- sarcoplasmic reticulum =
- Transverse (T) tubule = action potential travels down
- Lateral sacs = calcium ion is stored
- As the action potential travels down T-tubles, calcium is going to diffuse out of the lateral sacs.
- In presence of calcium and binding to tropomyosin, sites open to bind
    - All of this takes energy = ATP

Myosin ATP Site;

- ATP molecule binds to this site
- ATP binding – splits into ADP
    - Energy is released when release of P
    - Cross bridge energized

Types of Fatigue:

A. Muscle Fatigue;
    a. Muscle cannot respond to stimulation with same response of contraction
B. Neuro Muscular:

    a. Motor neurons cannot synthesize Ach fast enough to respond.
C. Psychological Fatigue:
    a. CNS does not activate

Muscle Fiber Types: based on speed of contraction and method used to make ATP.

A. Fast Oxidative Fibers:
    a. Relie on oxidative phosphorliaztion
    b. Many mitcondria
    c. Requires oxygen
    d. Myoglobin: red meat
    e. Fatigue resistant
        i. Power sprints
B. Fast Glycolytic:
    a. Uses glycolysis
    b. Less vascularized
    c. Less mitochondria
    d. Less myoglobin: white meat
    e. Suseptalbe to fatigue

C. Slow Oxidative:
    a. Endurance acitivity
    b. Motor unit size decrease
    c. Neural activity to muscle decreases

Muscle Spindles:
- have afferent innervation
- stretch cause action potential to CNS.